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Modelling and Risk Management in the Offshore and Marine Industry Supply Chain

Regular Paper

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Abstract Supply chain risk management is primarily a process that involves the identification, assessment and mitigation of risks that arise in a particular supply chain system. Pertaining to that, the offshore and marine industry is one of the many industries that have seldom received much consideration when it comes to management of the supply chain system. The rig building facet of the offshore and marine industry was thus chosen as the main focus of the project to manage the risks that arise in a particular oil rig building project. A risk mitigation plan framework was proposed to act as a guideline to identify as much risk as possible, eliminate trivial ones, and subsequently, prioritizing the remaining ones. The final step involves the formulation of a mathematical model based on the selected risk. In this case, the risk of raw material price fluctuation is studied. The demonstration of the Monte Carlo simulation using the Risk Solver program was also done to quantify the risks. Two case scenarios were then developed along with the implementation of risk management techniques in order to observe the effectiveness of the risk management of the overall rig building supply chain.

Keywords Risk management, simulation, risk mitigation, marine and offshore industry.

1. Introduction

In the era of globalization, supply risk management has attracted the attention of different industries, including the marine and offshore industry. Although organizations attempt to further reduce existing risk before the risks have taken place, the trade-off of different preventive measures and scenarios should be considered. Apart from considering the risk handled by an individual party in the supply chain, there also risks which can be transmitted to other members of the supply chain in the case of risks not being managed well within the organization. Although more and more organizations have started to realize the importance of risk management, it is difficult to quantity the risk and conduct scenario analysis without data support. Hence, the objective of this paper is to develop a supply chain risk management model by utilizing the Monte Carlo simulation in quantifying and managing the risk in a supply chain system.

The organization of the paper is as follows. Chapter 1 introduces that 'Risk', as a form of uncertainty when making decisions and actions in a supply chain, is a very important factor to be considered. Chapter 2 reviews the related literature in supply risk management. Chapter 3 proposes the risk mitigation framework which involves steps to identify, assess and manage the type of risks that arise and exist as the greatest threat to a particular supply chain system. The final step of managing the risk with highest priority will make up the major part of the risk mitigation. Chapter 4 uses a case study to illustrate the proposed model in a practical situation in the offshore and marine industry due to the high risk impact of the supply chain system for offshore and marine projects. Chapter 5 concludes the findings and analysis of this research followed by suggestions of future work.

2. Literature Review

Supply risk management is slowly gaining more attention nowadays as more and more researchers and scholars are delving deeper to uncover better ways of managing risks. Risks in terms of supply chain are mainly unexpected events which might interrupt the smooth flow of materials along the supply chain. There are all types of definition when it comes to supply chain risks; most definitions are similar, but if there is a difference, this only depends on the type of factor that is considered when defining supply chain risk. For example, Wu [2]defines it as an element form from the supply chain's multi-link feature which exposes it to adverse factors from the external environment and internal entity. Meanwhile Yossi Sheffi concentrates more on terrorist attacks, such as the September 11 terrorist attack, and the fact that terrorism is one risks to the supply chain which can cause the greatest impact, making all supply chain members vulnerable [3]. Tang on the other hand states that supply chain risk can be divided into disruption risk and operational risk in which, the causes of which are external factors and inherent uncertainties respectively [4]. In terms of the perspective of default, Zhang and Li state a phenomenon called default correlation whereby supply chain risk is eventually related to the default of member enterprises.

Numerous supply chain risk management models have also been proposed to further allow the control of supply chain more effectively. For example, the model proposed by Pujawan and Geraldin which uses the house of risk model that is separated into two deployment stages. The first, HOR1, focuses on ranking risk agents according to their risk potentials, the second HOR2 focuses on prioritizing proactive actions in order to deal with the selected risk agents in HOR1. Wang et al., on the other hand, proposed a controllable risk transmission model for construction of the supply chain. This model allows clarity of the transmission mechanism when transmission takes place between the raw material supplier and the construction enterprise. Another model which assesses the risk in supply chain systems is proposed by Liu et al., based on the usage of multistage influence diagrams. The influence diagrams allow risks to be evaluated and analysed scientifically and effectively by graphically describing the elements of risk assessment process while working with both controllable and uncontrollable risks.

More and more research and articles related to risk management across supply chain are emerging nowadays. Examples of businesses that are being researched on are electric power companies, pharmaceutical producers, building construction projects and even in software developers. All these allude to how big of an impact the new trends in supply chain are having on business planning. However, there is not sufficient research on the supply chain structure of marine and offshore companies. Even if some information regarding the risk management on the offshore and marine industry exists, this lacks a risk mitigation framework and simulation models on how the marine and offshore companies could manage the risk across the supply chain system.

3. Risk Mitigation Framework

In order to analyse and measure the risks, this paper proposes the following framework which is divided into four main steps and a quantitative method which takes place before the risk management step:

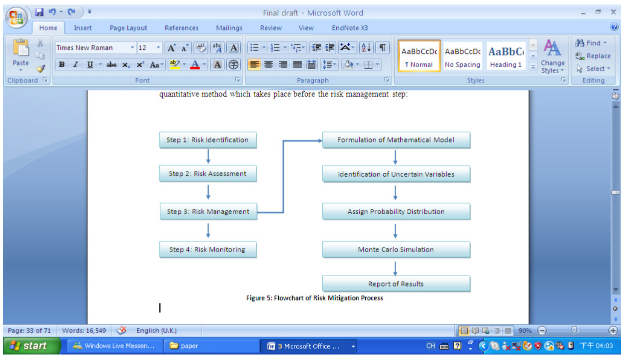

Figure 1. Framework of Risk Mitigation Process

3.1 Step 1: Risk Identification

The first step in understanding the process of risk transfer in the supply chain is to identify all the risks based on the context that is being dealt with. Investigation and research can be done to reveal the problems posed by such risk to the system. With such information at hand, the next step is to apply a certain method to identify all the risks leading to the problem. A variety of methods, depending on the type of industry and context can be used to do this. Some of the common risk identification methods are listed below:

1) Scenario-based – different scenarios exist as alternative ways to a particular objective. Based on this, any event that triggers an undesired scenario is identified as a risk.

2) Taxonomy-based – a breakdown of possible risk sources. A questionnaire is compiled based on knowledge of best practices. Finally the answer to the questions will reveal the risk.
3) Common risk checking – list with known risks are already available in certain industries. These risks can be verified by applying it to a particular situation.

3.2 Step 2: Risk Assessment

3.2.1 Primary Elimination of Available Risk

The author will be dividing this step into two stages whereby the first stage of the risk assessment process involves the practice of making the best educated guesses possible to screen out insignificant risk from the initial list from step 1. In this stage, risk with greater probability of occurring and greater loss is distinguished from risk with lower probability of occurring and lower loss to the organization. Risks with low occurring probability and loss are therefore eliminated for the subsequent stage. To add on to that, the impact of the risk should not only be considered in a particular node of the supply chain, it is crucial that the context of risk transfer is taken into account. The impact of a certain risk might be low and have slight chances of occurring in a certain department, but this might be a different situation if the risk is transferred to another department.

3.2.2 Formulation of Mathematical Model

In the second stage, a mathematical model is created in order to identify the most critical risk and to prioritize the remaining ones from the list of remaining risks. In order to do this, the risks taken into account must be quantifiable which means that there must be a certain way in which the risks can be measured.

In order to produce an accurate model that will be able to achieve the above, priori information should be available as much as possible. Correct information or data will undoubtedly result in the model produced behaving in a correct or the expected way. To increase further the accuracy of the formulated model for a particular system, the following evaluations can be used. The first and easiest evaluation method is to test the model's fit to empirical data. This method utilizes the cross-validation practice whereby a certain set of data known as training data is first used to estimate the parameters for this model. Then another set of different data from the same system known as verification data will determine the model's accuracy, even though it is not used to set the parameters initially. Another evaluation method is to assess the scope of the model in which what range of data is applicable to.

With the available priori information and suitable model evaluation methods, the uncertain variables and constraints arising from the different types of risk can then be determined in order to produce the model. When this is done, the risk solver program is used to run a Monte Carlo simulation of the mathematical model. The risk solver program gives the ability to not only observe the effect of these risks on the result, for example net profit, but it is also able to tell which risk causes a greater impact on net profit. From the simulation, prioritization of the risk can then be done to aid the next step of risk management.

3.3 Step 3: Risk Management

Subsequently, the risk management process takes place whereby applicable and effective controls are used to manage the risk one by one starting from the risk that has the highest level of prioritization ascertained from the earlier step. Suggestions to mitigate the risks are proposed and tested in order to find out which of these decisions will work best. Some of these risk mitigation decisions are as follows:

a) Purchase an insurance policy for a particular risk in order to transfer the risk to the insurer. This method is common as it is a way to transfer all the possible risks to another party without making any amendments to the organizations system or goal.
b) Avoid the risk by simply not engaging in any activity that gives rise to the risk. Although this is a method of dealing with risk, it is considered as a negative technique which is unlikely to be practiced in the business environment.
c) Risk retention is the most common method used. In certain cases, retaining the risk is by far the best possible method compared to spending great amounts in reducing it. Other than that, some risks are simply not taken into consideration which would not result in any harm to the party, although loss has occurred because in the first place it was not considered as a risk at all. However, such risks being dealt with through this way mostly lead only to relatively small losses.
d) Reducing risk by having loss prevention and controls. Efforts are made in ensuring safety programmes and loss prevention measures, such as ensuring fire departments, sprinkler systems, burglar alarms and medical care all work correctly and are in proper condition. Through these ways, the occurrence of loss can be prevented or if it is not preventable, the severity of loss could be reduced.

3.4 Step 4: Risk Monitoring

The last step in the whole risk mitigation process is through risk monitoring. All risk management plans and techniques are initially imperfect to a certain degree. It is only through practice and the actual experience of loss that better risk management is reached. Therefore it is always necessary to update risk analysis results and management plans periodically for the following purpose:

a) To ensure that the risk management techniques being practised are still effective.
b) To ensure that the techniques used will be able to deal with new risks that exist or in other words are in line with the dynamic characteristic of the business environment.

4. Case Study

An overview study on the marine and offshore industry supply chain is done in order to understand the workings and operations taking place. This is another essential step towards the simulation to allow every business to compete with the turbulent business environment by making better forecasts in purchasing and therefore, reducing unnecessary spending. The raw material that is the main focus here is the supply chain of steel.

Some of the more common risks that marine and offshore industries face, with consequences on the organization if ever such a risk is to become reality, include project delay, raw material price fluctuation, insufficient storage space, sole supply from single supplier, etc.

Two policies related to raw material price fluctuation have been created for this research, these are Make-To-Order and Purchase-In-Abundant applied on each of the risk mentioned earlier. A brief description of the constraints for the mathematical model is given below.

1) Steel Plate Quantity – the total average steel plate quantity that will be used for a particular oil rig project amounts to up to 6000 metric tonnes.
2) Steel Plate Price – the steel plate market price range that has been allocated for the model ranges from \$639 to \$828 based on a monthly steel price chart obtained from the month of October 2009 to December 2010.
3) Inventory Holding Cost Rate – an interest of 5% of the total steel cost per month has been set for the inventory holding cost.
4) Stock Keeping Period – a period of two months has been decided for the storage of extra steel plates purchased.

4.1 Make-to-Order vs. Purchase-In-Abundant Policy

The first scenario relates to the risk of raw material price fluctuation whereby steel will be the only raw material considered. The initial condition is where the procurement department of the marine and offshore company is applying the Make-to-Order policy when it comes to purchasing steel plates. This means that the steel plates will only be purchased by the procurement department when the company has received a contract to build an oil rig. Subsequently, the new Purchase-In-Abundant policy is implemented whereby the market prices of steel plates are monitored from time to time. Whenever the price hits a level low enough that is acceptable to the marine and offshore company, steel plates will be purchased in abundance to the point that it will be sufficient to be used for at least two rig building projects. However, inventory holding costs will be incurred due to stock safety needs.

4.1.1 Parameter Setting of Make-to-Order Policy

The scope of raw material is lowered down to only steel plates. Next, considering the scenario whereby the Make-to-Order purchasing policy is implemented, three price scenario cases are created as an analogy to the market condition. In this case, there is the minimum, most likely and the maximum price scenario. Based on past records from the year 2009 to 2010, the following steel plate prices for each scenario that will be used in the spreadsheet are shown in Table 1 below:

Scenario	US\$/tonne
1)Minimum price	639
2)Most likely price	746.8
3)Maximum price	828

Table 1. Steel plate price range when Make-to-Order Policy is implemented

Following that, a triangular distribution with the following formula is created in the cell below in order to generate a random market steel price each time a new simulation is run.

Price/tone =PsiTriangular(639, 746.8, 828)

The currency that is used for the price in this case is the US dollar. The main reason that no alteration is made in the currency is because the business dealings of the oil and marine industry have been done using US dollars from the very beginning. Therefore, converting the currency to SG dollars is not done in order to minimize the currency exchange risk. In addition, most of rig owners are US-based according to a reliable source from the steel manufacturer.

The total steel plate cost and the true total steel plate cost formula that is used in the spreadsheet are shown in Table 2.

Item	Cell	Value/Formula
Total Cost of Steel Purchased	B14	=B13*6000
Total Cost(2 rigs)	B15	=B14*2
True Total Cost (2 rigs)	B16	=PsiMean(B15)

Table 2. True total steel plate cost equations and value with respect to Make-to-Order policy

4.1.2 Parameter Setting of Purchase-In-Abundant policy

Next, the scenario of forecasting and Purchasing-In-Abundant policy is implemented. The steel price are taken from the past history to set the minimum price, average price and maximum price, thereby forming a new set of distribution figures as shown in the Table 3, followed by the formula that is inputted into the cell to generate the steel plate price with respect to the Purchase-In-Abundant policy.

Price Scenario	US$/tone
Minimum Price	$639.00
Average Price	$692.90
Maximum Price	$746.80

Table 3. Steel plate price with respect to Purchase-In-Abundant policy

The below distribution is used to generate steel plate price/tonne with respect to Purchase-In-Abundant policy

Price/tonne=PsiTriangular (639, 692.90,746.80)

Inventory costs will be incurred in this part with the cell formula and Table 4 depicts the total steel plate cost and true steel plate cost below:

Item	Cell	Value/Formula
Inventory Holding Cost per Month	E33	=B32*(5/100)*0.5
Total Cost of Steel Purchased	B32	=E32*12000
Total Inventory Holding Cost	B33	=E33*2
Total Cost	B34	=B32+B33
True Total Cost	B35	=PsiMean(B34)

Table 4. True total steel plate cost equation and value with respect to Purchase-In-Abundant policy

4.2 Results

From the suggested model and the utilization of Monte Carlo simulation, the following simulation results below are obtained.

4.2.1 True Total Cost of Steel Plates

The true total cost of steel plates purchased to build the rigs may be different from the rough calculation of the total cost initially. The main reason for this is because the total cost of steel plate calculated is only based on a randomly generated value of steel plate price using the triangular distribution.

The true total cost of steel plates on the other hand is based on 1000 cases of randomly generated values of the steel plate price in order to re-enact the case of the steel plate market price scenario. In order to manage the price flotation of the raw material, a company implements monitoring and forecasting. In order to show the effectiveness of the measure, 4.2.2 shows the result without monitoring and forecasting while 4.2.3 shows the result of implementation of forecasting and monitoring.

4.2.2 Without Monitoring and Forecasting

Figure 2 illustrates the simulation results for 1000 trials to determine the true total cost of steel plates when forecasting and monitoring of the steel market price behaviour was not done at all.

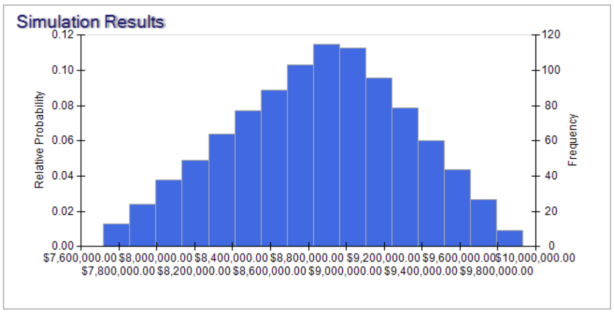

Figure 2. Simulation results of steel plate cost before implementation of forecasting and monitoring

The risk solver is also able to provide a summary of statistics information. The following shows the statistics information that has been obtained:

Statistic	Value	Statistic	Value
Mean	$8,855,189.05	Minimum	$7,708,157.41
Standard Deviation	$464,764.75	Maximum	$9,900,070.60
Mode	$8,972,206.34	Range	$2,191,913.19

Table 5. Steel plate cost statistical information before implementation of forecasting and monitoring

For this simulation, each time a new Monte Carlo simulation is run or in other words another new 1000 trials is run, the true mean total steel plate cost will stay at around a value of $8,855,000. This basically sums up the total steel plate expense of an oil rig project using 12000 metric tonnes of steel plates.

4.2.3 Implementation of Forecasting and Monitoring

Figure 3 illustrates the simulation result to find the true total cost of steel plates for forecasting and monitoring of the steel market price. In order to buy steel plates at a low price, a company may keep extra stocks while incurring extra inventory costs.

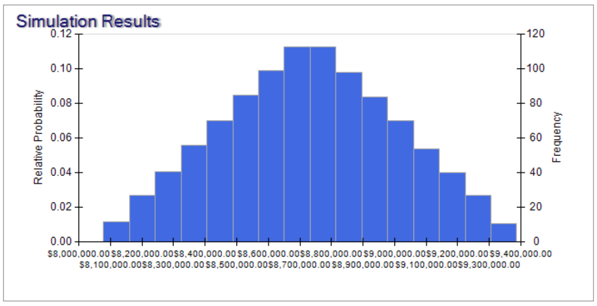

Figure 3. Simulation results of steel plate cost after implementation of forecasting and monitoring

The statistical information for this simulation is shown in Table 6 below.

Statistic	Value	Statistic	Value
Mean	$8,730,543.52	Minimum	$8,078,534.79
Standard Deviation	$277,361.49	Maximum	$9,386,989.94
Mode	$8,729,207.46	Range	$1,308,455.15

Table 6. Steel plate cost statistical information after implementation of forecasting and monitoring

For this simulation, each time a new Monte Carlo simulation is run or in other words another new 1000 trials is run, the true mean total steel plate cost will stay at around a value of $8,730,000 which is lower than the mean total steel plate cost without forecasting and monitoring. This is the average total steel plate expense of two oil rig projects and each time 12000 metric tonnes of steel plates are purchased.

5. Conclusion

This research started off by providing a basic background of the shipbuilding industry whereby the core business includes ship repair, vessel conversion, shipbuilding, rig building and offshore engineering. Being one of the toughest industries, the industry is constantly engaged in multimillion dollar projects. However, the ongoing supply chain system that is being applied in this industry consists of a lot of loopholes rendering the supply chain system inefficient and vulnerable to many different types of risk. Such risks that are either being ignored or the related company is totally unaware of, may cause great loss because of high cost or lowered amount of net profit.

In order to mitigate such risks, a risk mitigation framework is proposed in this paper to identify, assess, manage and monitor the risk. In the risk identification process, several existing risks which the company faces are listed out and will eventually go through the risk assessment process. Subsequently, the risk of raw material price fluctuation is studied and a mathematical model is then developed so as to quantify the risks. Out of the many different facets in this industry, an oil rig building project has been chosen as the case study. For the risk of raw material price fluctuation, steel plate was chosen out of the many raw materials that are used because it is the main raw material needed in oil rig building. Choosing only one material out of the many will contribute to the formulation of the basic model which can be improved later.

There are several factors regarding the model that could be improved if any further research is to be done. First of all, steel plates are the only type of raw material being considered for this model. However, many different commodities, such as copper and oil, are needed in a rig construction project. Addition of these into the calculation will definitely provide a better measurement on the grand total cost. Subsequently, the effectiveness of the risk management technique proposed in mitigating the risk of raw material price fluctuation can be further studied.

Secondly, rig projects may come in different sizes, meaning that the revenue earned could be different. Instead of taking only a constant or average value for every project, the real revenue earned based on a history of accomplished projects could be used in the model instead. As a result, the verisimilitude of the model could then be further improved.

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